AMENDMENTS TO THE SPECIFICATION

Please replace the paragraph beginning at page 1, line 10 with the following rewritten paragraph:

-- A steel pipe rockbolt, which is firmly fixed to a bedrock or ground in an expanded state, is manufactured from a hollow shaped pipe having one or more expansive concavities extending in an axial direction. The steel pipe rockbolt 1 has a sealed end, which is inserted into a rockbolt-setting hole formed in a bedrock or ground 2, as shown in Fig. 1. There is a vacancy between the rockbolt-setting hole and the un-expanded steel pipe rockbolt 1 (Fig. 2A). The steel pipe rockbolt 1 is expanded by a hydraulic pressure (Fig. 2B) provided by the hydraulic pump 3, and finally pressed onto an inner wall of the rockbolt-setting hole (Fig. 2C). Consequently, the bedrock or ground 2 is reinforced with the rockbolt 1. --

Please replace the paragraphs beginning at page 2 line 5 and ending at page 3, line 19 with the following rewritten paragraphs:

-- The expansive steel pipe rockbolts are classified to a 110 kN group and a 170 kN group by the yield strength necessary for construction conditions, e.g. competence and geomechanics of a bedrock or ground as well as cross-sectional profiles of tunnels. Rockbolts, which belong to the 110 kN group, are manufactured from steel sheets of 2 mm in thickness with a tensile strength of 300 N/mm^2 or more and a total elongation of 30% or more. Rockbolts, which belong to the 170 kN group, are manufactured from steel sheets of 3 mm in thickness with a tensile strength of 300 N/mm^2 or more and a total elongation of 35% or more. In any case, the steel sheet is formed to a cylindrical pipe of 54 mm in outer diameter and further reformed to a shaped pipe of 36 mm in outer diameter with a concavity 4.

The shaped pipe is manufactured by partially bending a cylindrical pipe with a small bending radius in a sectional plane, as shown in Fig. 2A. On the presumption that shaped pipes have the same outer diameter, a bending radius at a center is smaller as a thickness ~~increase of~~is increased for a steel sheet, which is formed to a shaped pipe. The shaped pipes are further swaged at its both ends, since sleeves having inner and outer diameters regularized in size are fixed to the end parts of the shaped pipes. A thicker steel sheet is reformed with a smaller bending radius even in the swaging process. That is, a local

bending radius becomes smaller as ~~an~~a thickness increase of a steel sheet for raising strength of a rockbolt.

By the way, many strains are introduced into a steel sheet in a pipe-making process, a pipe-shaping process and a swaging process. Strains are also accumulated during hydraulic expansion of a shaped pipe. When the shaped pipe is further expanded, it is often cracked due to the introduction of additional strains. Cracking causes leakage of a pressurized fluid, insufficient expansion of the shaped pipe and a shortage of the strength necessary for a rockbolt.

SUMMARY OF THE INVENTION

The present invention aims at ~~provision of~~providing high-strength steel pipe rockbolts with high reliability. An object of the invention is to inhibit cracking of rockbolts, which are induced by strains introduced in a pipe-shaping process, a swaging process and a hydraulically expanding process. Another object of the invention is to initiate expansive deformation of the shaped pipe at a relatively lower pressure during hydraulic expansion and to complete the expansive deformation in a short time period.

The invention proposes a high-strength steel pipe rockbolt, comprising an expansive rockbolt main body formed from a shaped pipe having one or more concavities extending along an axial direction. The shaped pipe is manufactured from a high-strength steel sheet of 1.8-2.3 mm in thickness with a tensile strength of 490-640 N/mm^2 and an elongation of 20% or more. The shaped pipe preferably has a tensile strength of 530-690 N/mm^2 and an elongation of 20% or more. --

Please replace the paragraphs beginning at page 3, line 27 and ending at page 4, line 3 with the following rewritten paragraphs:

-- (1) A step of forming a high-strength steel sheet of 1.8-2.3 mm in thickness with a tensile strength of 490-640 N/mm^2 and an elongation of 20% or more ~~to~~into a welded steel pipe of 50-55 mm in outer diameter.

(2) A step of roll-forming the welded steel pipe ~~to~~into a shaped pipe having an outer diameter of 34.0-38.0 mm and one or more concavities extending along an axial direction. --

Please replace the paragraph beginning at page 5, line 5 with the following rewritten paragraph:

-- The inventive steel pipe rockbolt is manufactured from high-strength steel. Selection of the high-strength steel enables use of a thin steel sheet as material of the rockbolt. When a rockbolt formed from a thinner steel sheet is compared with a conventional rockbolt on the presumption that the rockbolts have the same outer diameter, a minimum bending radius of a curved part, which defines an axially extending concavity, is larger at a center along a radial direction. Strains, which are introduced into a steel pipe in a pipe-shaping process and hydraulic expansion of a shaped pipe,[[.]] are reduced in a total amount as a decrease of thickness of the steel sheet. Due to reduction of the strains, the shaped pipe is hydraulically expanded without cracking. Use of the thinner steel sheet also means lightening of the rockbolt. Consequently, the inventive rockbolt is good of handlability and workability with high reliability. --

Please replace the paragraph beginning at page 5, line 25 and ending at page 7, line13 with the following rewritten paragraphs:

-- For instance, a shaped pipe with a tensile strength of 400 N/mm^2, which has been used for a rockbolt with a yield strength of 170 kN, is manufactured by forming a steel sheet of 3 mm in thickness with a tensile strength of about 300 N/mm^2 and an elongation of about 35% to a welded steel pipe of 54 mm in outer diameter and reforming the welded pipe to a shaped pipe of 36 mm in outer diameter.

When a thin high-strength steel sheet is used as material for a 170 kN-class rockbolt, a strong and reliable rockbolt, which is hydraulically expanded without cracking, is obtained. In fact, a shaped pipe, which is manufactured by forming a high-strength steel sheet of 1.8-2.3 mm in thickness with a tensile strength of 490-640 N/mm^2 and an elongation of 20% or more to a welded pipe of 54 mm in outer diameter and then shaping the welded pipe to an objective profile of 36 mm in outer diameter, has a tensile strength of 530-690 N/mm^2. Consequently, a rockbolt, which is formed from the high-strength shaped pipe, is firmly fixed to a bedrock or ground with a strength of about 170 kN, by placing it in a rockbolt-setting hole of the bedrock or ground and hydraulically expanding it therein.

Use of a thinner steel sheet enables bending a surface part of a welded pipe with a larger bending radius in a pipe-shaping process. Presume that a cylindrical pipe of 54

mm in outer diameter is formed to a shaped pipe with a cross section shown in Fig. 2A, wherein a curved part (a concavity 4) has an outside bending radius of 5 mm. A shaped pipe, which is formed from a cylindrical pipe of 3 mm in thickness, has a curved part with an inside bending radius of 2 mm. On the other hand, a shaped pipe, which is formed from a cylindrical pipe of 2 mm in thickness, has a curved part with an inside bending radius of 3 mm. In short, as a decrease in thickness of a welded pipe (in other words, a steel sheet), a bending radius becomes larger, resulting in a reduction of cumulative strains during pipe-shaping. Reduction of the cumulative strains means an increase of a tolerance limit until the shaped pipe is cracked due to the accumulation of strains. Consequently, the inventive rockbolt is hydraulically expanded in a bedrock or ground without fears of bursting.

A thickness of a steel sheet is determined within a range of 1.8-2.3 mm in order to effectively reduce the accumulation of strains. If the thickness exceeds 2.3 mm, it is difficult to realize an increase of a bending radius in a pipe-shaping process. On the other hand, the thickness less than 1.8 mm means the necessity of a high-strength steel sheet with a tensile strength of 640 N/mm^2 or more, otherwise a strength of 170 kN or so would not be imparted to a rockbolt. However, such high-strength steel sheets can not be formed to an objective profile due to poor elongation in a pipe-shaping process, and shaped pipes useful as expansive rockbolts can not be manufactured with ease from welded steel pipes of 50-55 mm in outer diameter. Besides, steel sheets shall have a tensile strength of 490 N/mm^2 or more; otherwise rockbolts with 170 kN or so would not be manufactured from welded pipes of 50-55 mm in outer diameter. Elongation of 20% or more is also necessary, in order to hydraulic expand shaped pipes without bursting. --

Please replace the paragraph at page 8, line 18 with the following rewritten paragraph:

-- Presume that a pressure of 7 MPa is necessary for initiation of bulging of the concavity **4**, which is formed at a shaped pipe of 2 mm in thickness and that a pressure of 17 MPa is necessary for initiation of bulging of the concavity **4**, which is formed at a shaped pipe of 3 mm in thickness. When a ~~rockbolts~~rockbolt is hydraulically expanded with a supply air pressure of 0.6 MPa under the above conditions, an inflow rate of the high pressure water is varied in correspondence with an internal pressure of the rockbolt as follows: --

Please replace the paragraphs beginning at page 9, line 2 and ending at page 9, line 23 with the following rewritten paragraphs:

-- Once the bulging of the concavity 4 starts, the expansive deformation of the shaped pipe continues at a pressure lower than the expansion-initiating pressure, and the expansion mode is substantially constant ~~nevertheless~~regardless of the thickness of the shaped pipe. After the shaped pipe is expanded to a size corresponding to an inner diameter of a rockbolt-setting hole in a bedrock or ground, an additional pressure is further applied to the expanded rockbolt so as to press the expansively deformed pipe onto an inner wall of the rockbolt-setting hole.

Although the thinner shaped pipe is expansively deformed by an internal pressure of 7 MPa, the internal pressure is necessarily raised to 17 MPa for the expansive deformation of the thicker shaped pipe. Injection of high-pressure water shall be continued at a discharge rate corresponding to a discharge pressure of 7-17 MPa. As a result, a hydraulic pump shall be compensatorily driven for a longer time. Moreover, a pressure for further expansive deformation is higher compared with the thinner shaped pipe, so that it is obliged to inject high-pressure water in a higher discharge pressure region, in other words, a small discharge rate region, for continuation of the expansive deformation of the thicker shaped pipe. In short, a time period for hydraulic expansion of the thicker shaped pipe is longer than that for the thinner shaped pipe. The completion of expansive deformation in a short time is also the advantage originated in the thinner rockbolt made of high-strength steel. --

Please replace the paragraph beginning at page 9, line 26 with the following rewritten paragraph:

-- A high-strength steel sheet of 1.8–2.3 mm in thickness with predetermined mechanical properties is processed ~~to~~into a welded pipe having an outer diameter of 50–55 mm by a conventional pipe-making process using high frequency welding, laser welding, TIG welding or the like. The welded pipe is roll-formed to a shaped pipe having an outer diameter of 34–38 mm and a dented sectional profile defined by a circumferential part and a concavity. --

Please replace the paragraph beginning at page 14, line 1 with the following rewritten paragraph:

-- A plating layer may be **Zn**, **Zn-Al** or **Zn-Al-Mg**. A **Zn** plating layer is preferably formed on a steel base by immersing a steel strip in molten zinc containing 0.1–0.2% of **Al**, which suppresses growth of a **Fe-Zn** alloy layer harmful on workability. A **Zn-Al** plating layer, e.g. **Zn**-5% **Al** or **Zn**-55% **Al**, exhibits corrosion-resistance 2–4 times better than a **Zn** plating layer of the same thickness. A **Zn-Al-Mg** plating layer is hard and exhibits the optimum corrosion-resistance, so that a rockbolt coated with the hard **Zn-Al-Mg** plating layer is placed and expanded in a bedrock or ground without scratches caused by abrasion with the bedrock or collision of scatters. Scratching is also inhibited during handling or transporting the coated rockbolt. Since scratches, which act as starting points of corrosion, are scarcely formed, the embedded rockbolt maintains good durability and reliability in addition to the excellent ~~corrosion-resistant~~corrosion-resistance even in a corrosive environment. --

Please replace the paragraphs beginning at page 16, line 6 and ending at page 16, line 29 with the following rewritten paragraphs:

-- A Fe-Al intermetallic compound, harmful on workability and formability of the coated steel sheet or pipe, is more formed as an increase of Al in the Zn-Al-Mg plating layer. The Fe-Al intermetallic compound at a boundary between a base steel and a plating layer unfavorably causes peeling-off of the plating layer during working or forming of a coated steel sheet or pipe. Formation of the intermetallic compound is inhibited by inclusion of Si at a small ratio in the plating layer.

EXAMPLES

A high-strength steel sheet of 2.1 mm in thickness with a tensile strength of 490 N/mm^2 and an elongation of 28% was processed ~~to~~into a welded pipe of 54 mm in outer diameter. The welded pipe was roll-formed to a shaped pipe of 36 mm in outer diameter with a sectional profile, as shown in Fig. 2A, having a concavity 4 extending along an axial direction. The shaped pipe had a tensile strength of 550 N/mm^2.

The shaped pipe was sized to a length of 4 m. End parts in longitudinal length of 75 mm from the edges of the sized pipe were swaged to a profile of 33.1 mm in outer diameter. A sleeve of 33.1 mm in inner diameter, 38.1 mm in outer diameter, 2.5 mm in

thickness and 70 mm in length was fixed to one end part, and the end part was sealed with the sleeve by welding. Another sleeve of 33.1 mm in inner diameter, 41.1 mm in outer diameter, 4.0 mm in thickness and 70 mm in length was fixed to the opposite end part at a side for introduction of a pressurized fluid, and the end part was sealed with the sleeve by welding.--